

NOHR Engineering Company, LLC

CONSULTING ENGINEERS

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March 3, 2015

NOHR # 2015021RepTepicMX 02 04 15

SIoux Steel Company
196 1/2 East 6th Street
P.O. Box 1265
Sioux Falls, SD 57101-1265

Attn: Mr. Chris Nelson
Ms. Amy Ellis

RE: Engineering Investigation Report on Collapse Cause and Origin
SIoux Steel Hopper Bin
Placed into service approximately 3 months prior to the collapse
Tepic, Nayarit, Mexico Location



Date of Collapse: Monday, February 2, 2015, approximately 7:40 A.M.

Owner: Agropecuaria el Avión
Mr. Miguel Castro
Avenida las Torres #610
Tepic, Nayarit, Mexico

Information and Data:

1. SIoux STEEL Hopper Bin
 - 30' diameter x 12 ring (44" side wall ring sheet height) with a 45° slope, center discharge conical hopper supported on 20 support legs.
 - 1022 cubic meter capacity
 - Soymeal fill weight capacity: 720 kilos per cubic meter x 1022 cubic meters = 735,840 kilos maximum.
2. Special equipment on the Hopper Bin
 - Five (5) – PNEUMAT air cannons around the bin wall base circumference
 - Five (5) – PNEUMAT air cannons around the hopper circumference at the hopper's mid-height.
3. Soymeal Stored in the Hopper Bin Per Owner Supplied Information
 - Soymeal imported from BUNGE USA
 - 11-1/2 % moisture
 - 47% protein
 - 720 grams/liter (720 kilograms/cubic meter)

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- At ambient temperature
 - On Wednesday, January 28, 2015 at 04:48:47 PM:
681,820 kilos of soymeal in the silo
681,820 kilo/735,840 kilo max capacity = 93% of capacity
4. Temperatures during the day on January 27th and January 28th ranged from 60 to 90°F, averaging 75°F, with humidity levels ranging from 25% to 94%, averaging 60% with no rain.
 5. By February 1st and 2nd, the weather was rainy and temperatures had dropped to the 55° to 67° F range and humidity had risen.
 6. After being filled on Wednesday, January 28, 2015, no soymeal was removed from the hopper bin until the morning of Monday, February 2, 2015.
 7. Stored soymeal was stationary in the bin and hopper for 4.5 days.
 8. Withdrawal of soymeal from the bin was started at about 7:30 A.M. on Monday, February 2, 2015.
 9. The bin's hopper bottom failed suddenly and hopper sheet seams split and spread open from the hopper cone bottom upward at approximately 7:40 A.M. as two workmen were working under the bin at the hopper bin's discharge and reclaim conveyor to start and maintain soymeal flow from the hopper bin.
 10. A security video shows the bin's air cannons were operating (puffs of dust) prior to the bin hopper's failure.
 11. The security video also showed one of the men reaching up and hammering on the bin's hopper prior to the hopper failure.

Narrative:

NOHR learned of the hopper bin's failure late in the afternoon on Monday, February 2, 2015, when Mr. CHRIS NELSON with SIOUX STEEL COMPANY telephoned and asked if NOHR was available to travel to Tepic, MX to view the damaged hopper bin and investigate the cause and origin of the failure. On the morning of Tuesday, February 3, 2015, Mr. NELSON telephoned and asked NOHR to travel to Tepic, MX as soon as practical to investigate and gather information regarding the cause and origin of the hopper bin's failure for NOHR's use in preparing a cause and origin report on the bin's failure.

NOHR arrived in Guadalajara, MX the evening of Tuesday, February 3, 2015. On the morning of Wednesday, February 4, 2015, Mr. LUIS MANUEL with MOLINOS AZTECA arrived at the hotel in Guadalajara, MX and transported NOHR by car to the AGROPECUARIA EL AVIÓN Feed Mill site in Tepic, MX where the failed hopper bin was located.

NOHR, accompanied by Mr. MANUEL, arrived at AGROPECUARIA EL AVIÓN at approximately 10:30 A.M. and waited at the gate until Mr. MIGUEL CASTRO arrived. Mr. CASTRO identified himself as the owner of the AGROPECUARIA EL AVIÓN Feed Mill. Mr. CASTRO accompanied

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NOHR during the visual inspection. MEXICO DEPARTMENT OF LABOR personnel were on site during NOHR's investigation.

Close, hands-on access to the damaged hopper bin was restricted for safety reasons. Mr. CASTRO and the MEXICO DEPARTMENT OF LABOR personnel asked for copies of this report. NOHR informed MEXICO DEPARTMENT OF LABOR personnel and Mr. CASTRO that the distribution of the report must come from Mr. CHRIS NELSON of SIOUX STEEL COMPANY.

NOHR took field notes and photos of the damaged hopper bin and the surrounding site using a camera and telephoto lens. Photos were taken of the failed bin from the ground level and from the adjacent mill's roof level.

On site, NOHR's questions regarding physical property data on the bulk soymeal stored in the bin, the amount of soymeal stored in the bin, when the soymeal was placed in the bin and how long the soymeal was in the bin were readily answered by Mr. CASTRO and his employees. Inventory data sheets showing the amount of soymeal in the bin on Friday, January 28, 2015 prior to the Monday, February 2, 2015 hopper bin failure were later provided to NOHR, confirming information verbally provided to NOHR on site.

On site, NOHR learned from Mr. CASTRO that a security camera at the mill's truck scale location had recorded the bin's failure. Mr. CASTRO arranged for NOHR to view the video. The video documents two men working under the hopper bin at about 7:30 A.M. on Monday, February 2, 2015. It appeared that the two men were working inside the hopper bin's support leg circle and below the bin's hopper to start withdrawing soymeal from the bin by feeding the soymeal into a reclaim conveyor.

NOHR was informed that soymeal reclaimed from the hopper bin would be moved by a reclaim conveyor into the adjacent feed mill. Prior to this time, approximately 4.5 days had elapsed since the last delivery and placement of soymeal into the hopper bin. No soymeal was withdrawn from the hopper bin in the preceding 4.5 days.

The Bin:

Stored soymeal over time settles and consolidates in bins and will develop a stationary arch or self-supporting dome as soymeal below a stationary dome of consolidated and settled soymeal is withdrawn and emptied, leaving a void area below the self-supporting dome of soymeal in the bin.

The bin and its hopper were fitted with compressed air cannons to help maintain soymeal flow from the hopper bin. The use of air cannon is intended to help minimize chances of soymeal bridging and developing stationary arched domes of settled and consolidated and soymeal above voids. Development of void areas below bridges of stationary domes of soymeal in the bin and hopper prevent soymeal from freely flowing out through the hopper bin's cone bottom discharge to the reclaim conveyor.

Per Mr. CASTRO and NOHR's understanding, five PNEUMAT air cannons around the circumference of the bin wall base (above the hopper) operated using compressed, dried air with the compressor set at 140 PSI, with one air cannon triggering consecutively in 20-second intervals, working counter-clockwise around the bin. Next, the 5 air cannons located around the bin's hopper at mid height also operated consecutively at 20 second intervals, working counter-clockwise

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around the hopper cone before the wall base air cannons operated again, continuing repetitive cycles of operation. A full and complete air cannon firing cycle of the ten (10) air cannon takes about 200 seconds (3.5 minutes) from start to finish. The air cannon firing cycle repeats automatically when operating.

From the security video, dust particles were observed being blown out in occasional spurts at the hopper cone discharge to reclaim conveyor connection, as the hopper mounted air cannon operated during 2 or 3 repetitive cycles totaling between 5 and 6 minutes. After a few minutes, one of the men could be seen hammering on the hopper after soymeal in the hopper had discharged. Following soymeal evacuation of the hopper, a void area in the bin existed and a stationary, bridged, soymeal dome in the nearly full bin was still intact above the void. This created a dangerous condition with a void area inside the bin hopper area with a huge mass soymeal above the stationary domed soymeal.

When stored soymeal in a bin remains stationary for a long time period, the cohesive soymeal settles, consolidates and sticks together in a non-free flowing mass. When discharge is started from a bin where soymeal has settled and consolidated, soymeal above the hopper discharge will empty leaving a void area with soymeal in the bin above unmoving and supported by a stationary arched dome of settled and consolidated soymeal.

After another 1 or 2 cycles of operation of the hopper bin's air cannon system, a larger spurt of dust particles at the hopper bin's cone bottom and reclaim conveyor area can be seen in the security video. A man in the area under the hopper bin can be seen hurrying towards the air cannon system control panel mounted under the hopper bin on the inside face of the hopper bin's support leg structure on the side adjacent to the mill.

The bin's hopper cone sheet bolted vertical seams spread open instantaneously starting at the hopper cone bottom just above the reclaim conveyor and traveling upwards on the hopper. Soymeal spilled down and out of the bin, leaving the bin hopper sheets' top edges still bolted to the compression ring beam at the hopper bin's wall base.

Based on NOHR's on site observations, the hopper bin's conical roof was sucked in by the vacuum effect created when the mass of soymeal in the bin above the hopper rapidly slid down in the bin's side wall area as soymeal below rapidly spilled out of the damaged bin hopper below.

Cause and Origin of the Bin's Hopper Failure:

Soymeal had been placed in the hopper bin near the hopper bin's full capacity during warm/hot weather. In the days immediately following the arrival of soymeal, significant changes in weather patterns developed. The weather became rainy and more humid contributing to the consolidation of soymeal stored in the hopper bin. The soymeal in the nearly full hopper bin settled and consolidated over the 4.5 day period of rainy conditions before soymeal withdrawal efforts began on Monday, February 2, 2015.

The failure originated at the bin's hopper cone bottom immediately above the reclaim conveyor where hopper lower panel bolted vertical seams split and spread open. The bin's hopper cone bottom and lower hopper sheet panel vertical seams' failure and spreading open were caused by soymeal **mass flow impact loading** on the bin's hopper cone bottom resulting from the sudden collapse of bridged and domed soymeal above into an emptied out volume of void space in the

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hopper below. The sudden and rapid flow downward movement of the mass of soymeal in the bin above the hopper created a vacuum above the falling soymeal and below the hopper bin's roof, causing the roof to suddenly collapse into the bin.

The five air cannons in the bin's hopper at mid height of the hopper are installed to fire down the hopper slope. Air from the 5 air cannons on the hopper would follow the path of least resistance, pushing and moving soymeal downward towards the hopper cone discharge and reclaim conveyor. The bin's hopper cone emptied from the hopper's air cannon level down, leaving a void.

Air cannon operation at the bin wall base level then broke loose the mass of settled, consolidated and domed soymeal above the void area. The uncontrolled and violent downward mass flow of soymeal into the void area below caused enormous impact loading on the bin's hopper, which split and spread open from the cone bottom up.

Attachments:

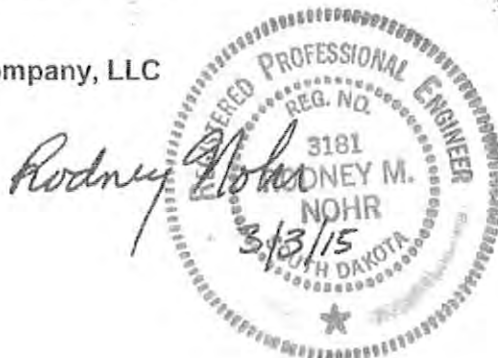
1. SIOUX STEEL Company Hopper Tank 35 – 1400 Metric Ton Capacities brochure
2. SIOUX STEEL Company "Erection Manual For... 27' – 36' Diameter Hopper Bin"
3. SIOUX STEEL Company "Owner's/User's Manual, 4" Corrugated Grain Bins"
4. PNEUMAT SYSTEM INC. Bulk Materials Handling Systems and Equipment internet brochure and advertising (7 pages)
5. PNEUMAT System Inc. air cannon layout and templates (4 pages)
6. Agropecuaria el Avión's hopper bin soymeal inventory sheets (2 pages) for Tuesday, January 27, 2015 to Wednesday, January 28, 2015 (681,820 kilos of meal) total prior to the hopper bin's failure.
7. Weather Underground Weather Data from the month of January 2015 (1 page)
8. Weather Underground Weather Daily Weather Data from January 27, 2015 to February 2, 2015 (34 pages)
9. NOHR's February 4, 2015 Photos and Field Notes #1 through #73

NOHR reserves the right to add to this report as more information becomes available. If more detail or information is needed, please call.

Sincerely,
NOHR Engineering Company, LLC

Rodney Nohr, PE

RMN/rs/bw



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Cc/file 2015021

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